



Bionomics of Black Soldier Fly: *Hermetia illucens* (Diptera: Stratiomyidae)

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E edible insects have emerged as a promising solution because of their high feed conversion efficiency, rapid reproduction, low environmental footprint, and superior nutritional value. Among them, the Black soldier fly has gained considerable attention for its potential in waste bioconversion, aquaculture, and livestock feed production. Prepupal larvae contain approximately 42% protein, 35% fat, essential amino acids, beneficial fatty acids, and nearly 44% dry matter, making them a nutrient-rich feed resource. The species undergoes complete metamorphosis through four life stages: egg, larva, pupa, and adult, with the entire cycle completed in about 45 days under favorable conditions. Females lay 500–900 eggs in cracks or crevices near decomposing organic matter, which hatch in approximately four days. The larval stage is the most active and economically important phase, lasting 18–20 days and comprising six instars. During this period, larvae aggressively consume manure, food waste, and decaying plant materials, significantly reducing waste volume while accumulating biomass. The pupal stage lasts one to two weeks, during which feeding ceases and internal transformation into the adult form occurs. Adults live for only 5–8 days, during which they mate, lay eggs, and die. Adult black soldier flies are harmless, non-invasive, and do not transmit diseases. Owing to these attributes, Black soldier fly represents a sustainable solution for future food security, organic waste valorization, and environmentally friendly feed production.

Key words – Adult, Black Soldier Fly, Eggs, Larvae, Pupa

Introduction

The unprecedented acceleration of global population growth, projected to reach nearly 9 billion by the year 2050, is expected to place immense pressure on existing food systems. As a consequence, worldwide food demand is anticipated to increase by almost 100% between 2005 and 2050 (MakkarHPS *et al.*, 2014). In contrast, agricultural production intended for both human consumption and animal feed is forecasted to rise by only 60% (Tomberlin *et al.*, 2015), thereby creating a substantial gap between supply and demand. This imbalance is likely to intensify concerns regarding global food security, particularly for staple crops that

constitute the foundation of human nutrition and livestock feed. Future shortages have been estimated for several major commodities, including maize, rice, wheat, and soybean, with projected deficits of approximately 67%, 42%, 38%, and 55%, respectively (RayDK *et al.*, 2013). Such figures underscore the urgent necessity for sustainable and innovative alternatives to conventional protein and feed resources. In this context, edible insects have emerged as a highly promising solution for both human food and animal feed industries. Their global appeal stems from numerous advantages, including superior feed conversion efficiency, rapid reproductive cycles, minimal land and water requirements, and remarkable nutritional value (VanHuisA *et al.*, 2013). Moreover, edible insects are already recognized and consumed in many parts of the world, highlighting their practical feasibility as an alternative protein source (OonincxDGAB *et al.*, 2015). Among the various edible insect species, the Black Soldier Fly has attracted considerable attention due to its exceptional potential in aquaculture and livestock production. During the prepupal stage, Black Soldier Fly larvae contain approximately 42% protein and 35% fat, along with essential amino acids and beneficial fatty acids. In addition, they consist of nearly 44% dry matter (BolandMJ *et al.*, 2013), making them a highly nutrient-dense and sustainable resource for future feed formulations.

Bionomics or Lifecycle

The Black soldier fly exhibits a holometabolous life cycle, meaning it undergoes complete metamorphosis through four distinct developmental stages: egg, larva, pupa, and adult. Under favorable environmental conditions, the entire life cycle is generally completed within approximately 45 days.

Eggs - The reproductive capacity of the Black soldier fly is remarkably high, with a single female typically depositing between 500 and 900 eggs during one oviposition cycle. This prolific egg-laying potential significantly contributes to the species' rapid population growth and its suitability for large-scale rearing systems. Rather than placing the eggs directly onto decomposing substrates, females strategically deposit them within narrow cracks, crevices, or sheltered spaces adjacent to decaying organic matter such as manure, compost, or food waste. This oviposition behavior provides protection from excessive moisture, microbial contamination, and predation, while ensuring that newly hatched larvae have immediate access to nutrient-rich feeding material. Under favorable environmental conditions, the eggs generally hatch within approximately four days (Silva and Hesselberg, 2019).

Larvae - The larval stage of the Black soldier fly represents the most metabolically active and economically significant phase of its life cycle. During this period, the larvae—commonly referred to as maggots—exhibit vigorous feeding behavior, rapidly consuming large quantities of decomposing organic material. Their extraordinary appetite enables substantial reduction in waste volume, making this species highly valuable for organic waste bioconversion and sustainable waste management systems. Larval development is divided into six distinct instars, each characterized by progressive growth and physiological advancement. Throughout this developmental sequence, larvae increase in size from approximately 1.8 mm shortly after hatching to nearly 20 mm at maturity. Individuals reaching the upper size range are generally recognized as mature larvae, possessing maximal biomass and nutrient accumulation. Immediately upon emergence from the eggs, the newly hatched larvae commence feeding on a broad spectrum of organic substrates. Their diet commonly includes animal manure, decomposing fruits and vegetables, household food residues, and various biodegradable wastes. Feeding intensity remains moderate during the early instars but rises markedly after the third instar, when larvae display accelerated growth and heightened substrate consumption. Upon reaching the sixth and final instar, the larvae enter a transitional phase marked by melanisation, during which the cuticle gradually darkens in color. This pigmentation change signifies the transformation into the prepupal stage. At this point, the insect evacuates its digestive tract, terminates feeding activity, and begins physiological preparation for pupation. Under favorable environmental conditions, the complete larval period generally extends for approximately 18 to 20 days. Owing to its rapid

development, efficient nutrient conversion, and remarkable waste-reducing capacity, the larval stage of the Black soldier fly is considered the most commercially important stage for feed production and waste valorization. (Agus *et al.*, 2020, Cuncheng *et al.*, 2019).

Pupa - The pupal stage of the Black soldier fly constitutes a critical transitional phase in its life cycle, during which the organism undergoes profound internal reorganization and metamorphic development. At this stage, the insect remains largely immobile and ceases all feeding activity, relying entirely on the nutritional reserves accumulated during the larval period. During pupation, the external body appears dormant; however, extensive physiological transformation occurs internally as larval tissues are reorganized into adult anatomical structures. This quiescent phase is essential for the successful progression from the immature form to a fully developed adult fly. The pupal period generally persists for approximately one to two weeks, depending on environmental conditions such as temperature, humidity, and rearing circumstances. In many cases, the insect remains inactive for at least eight days before emergence occurs. The completion of this developmental stage is marked by the eclosion of the adult Black soldier fly, signifying the beginning of the reproductive phase and the continuation of the species' life cycle. (Silva and Hesselberg, 2019).

Adults - The fourth and terminal phase of the life cycle of the Black soldier fly is the adult stage, which generally endures for approximately five to eight days. Although relatively brief in duration, this period is biologically significant, as it is exclusively devoted to reproduction and species continuation. During the adult phase, newly emerged flies seek mates, engage in courtship and copulation, and subsequently the females deposit egg masses in appropriate oviposition sites. Following the completion of these reproductive activities, the adults naturally die, thereby concluding their life cycle. Unlike the larval stage, adult flies consume little or no substantial food and depend largely on the energy reserves accumulated during earlier developmental stages. Importantly, the adult Black soldier fly is regarded as a beneficial and non-pest species. It does not damage agricultural crops, contaminate the environment, transmit major diseases, or invade residential areas, kitchens, or restaurants in the manner of nuisance flies. This characteristic makes it particularly valuable for sustainable waste management and insect-rearing systems. Furthermore, adult black soldier flies typically inhabit secluded environments away from close human activity. They preferentially mature, rest, and mate in shaded, vegetated, or sheltered locations where environmental conditions are favorable. Their discreet behavior and ecological harmlessness further enhance their suitability for commercial and environmental applications. (Cuncheng *et al.*, 2019).

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